α Centauri Bb

An RV planet detection
with minimum mass similar to Earth

Dumusque et al., Nature - Nov. 2012

The present state of the art for RVs

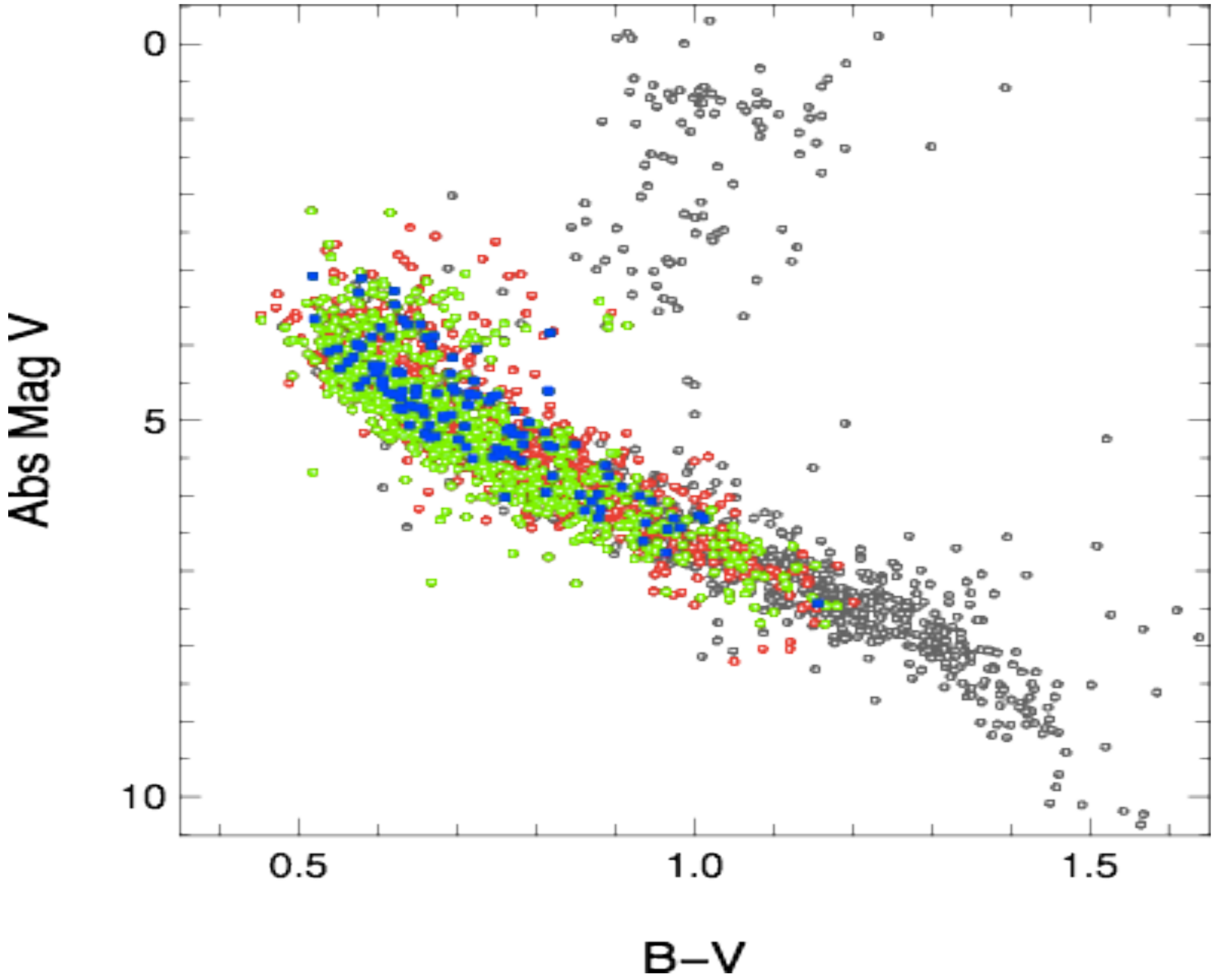
Thanks to Xavier and Michel for lending slides

But first the context for this result:

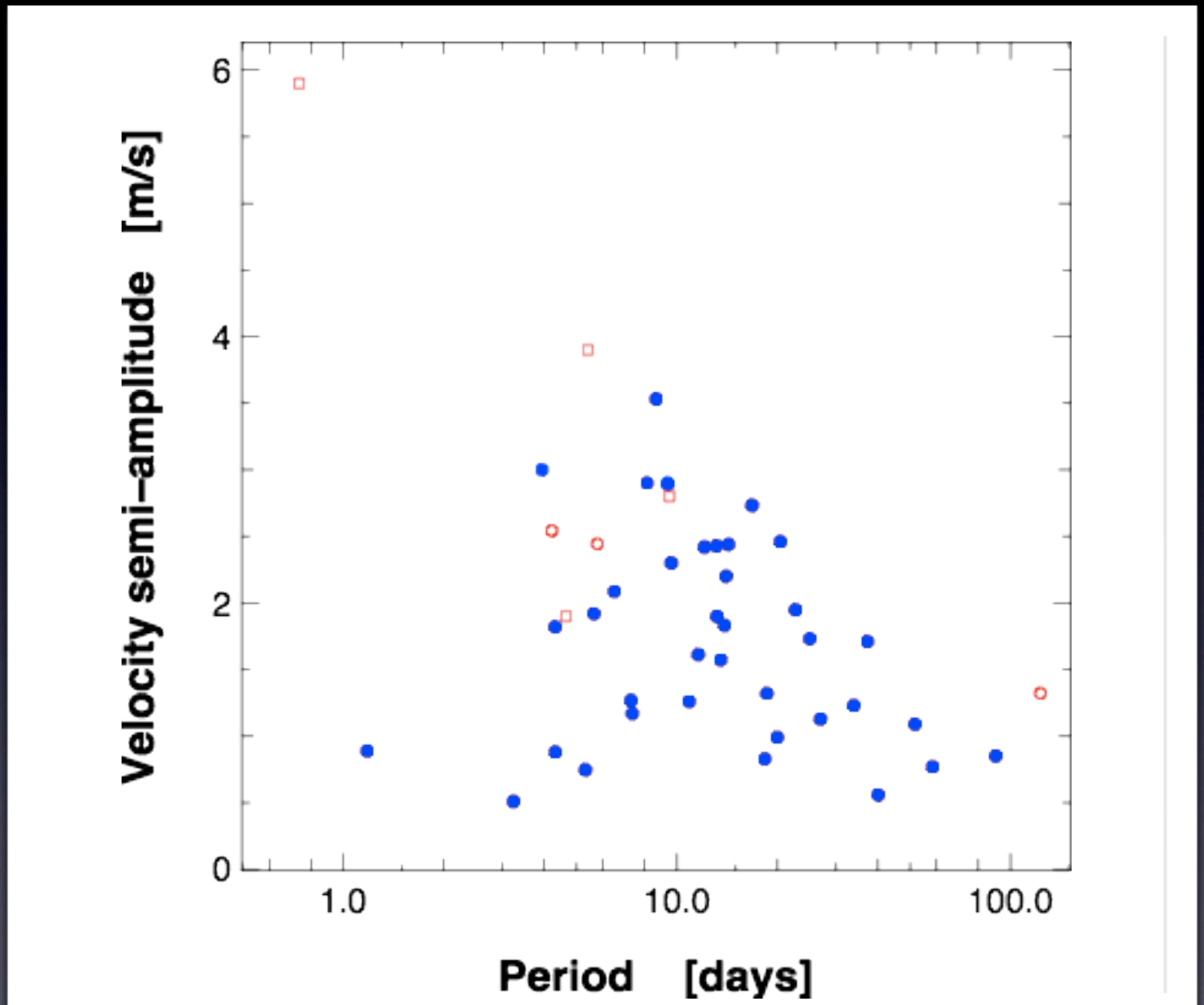
The HARPS Search for Southern Exoplanets

CORALIE reconnaissance (1998-now)
822 FGK stars, volume limited sample
low activity: log R'HK < −4.70

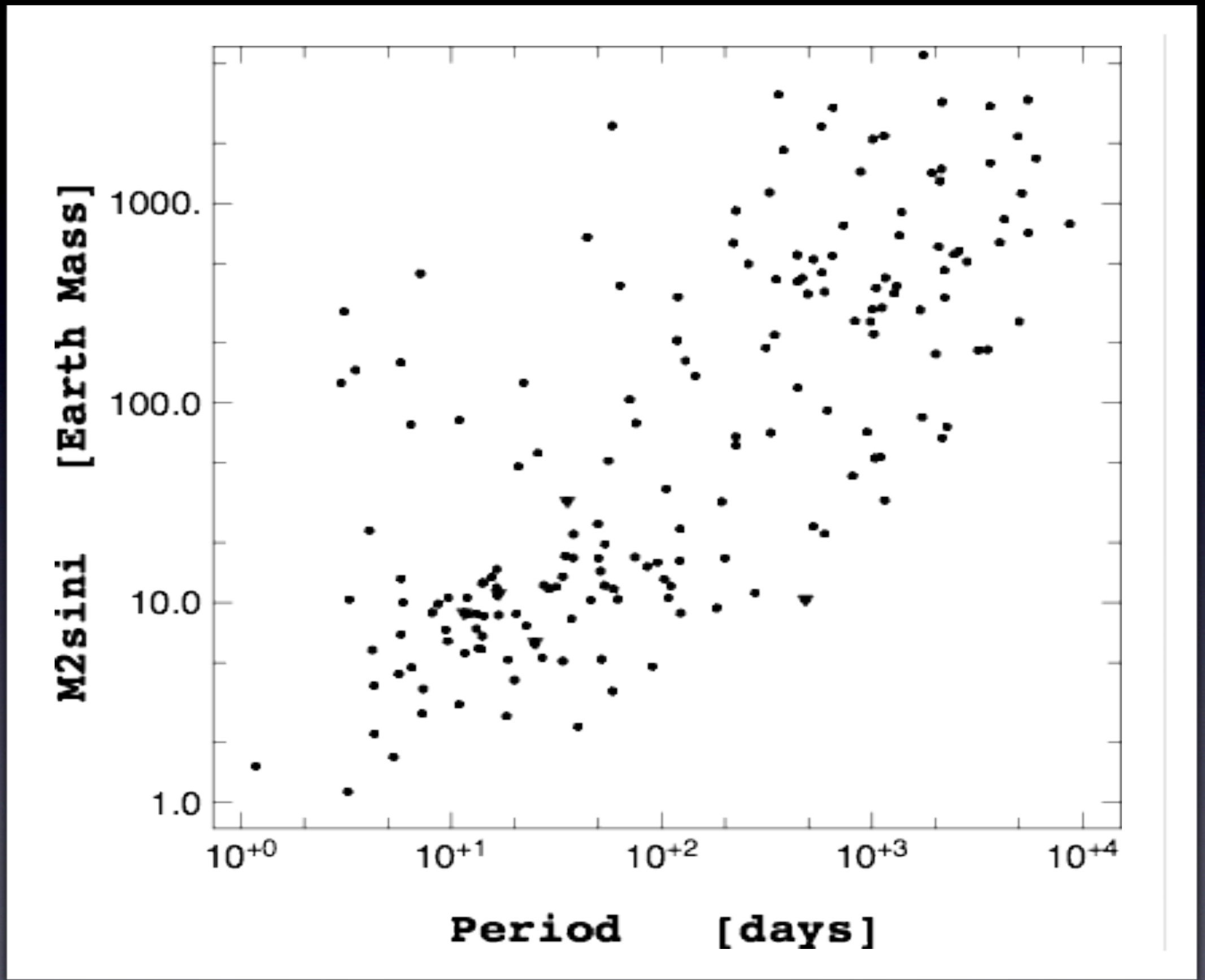
HARPS subsample (2003-now)
376 quietest stars, 490 nights
Measurement noise floor ≃ 0.7 m/s


0
5
10
Absolute Mag V
0.5
1.0
1.5
B–V

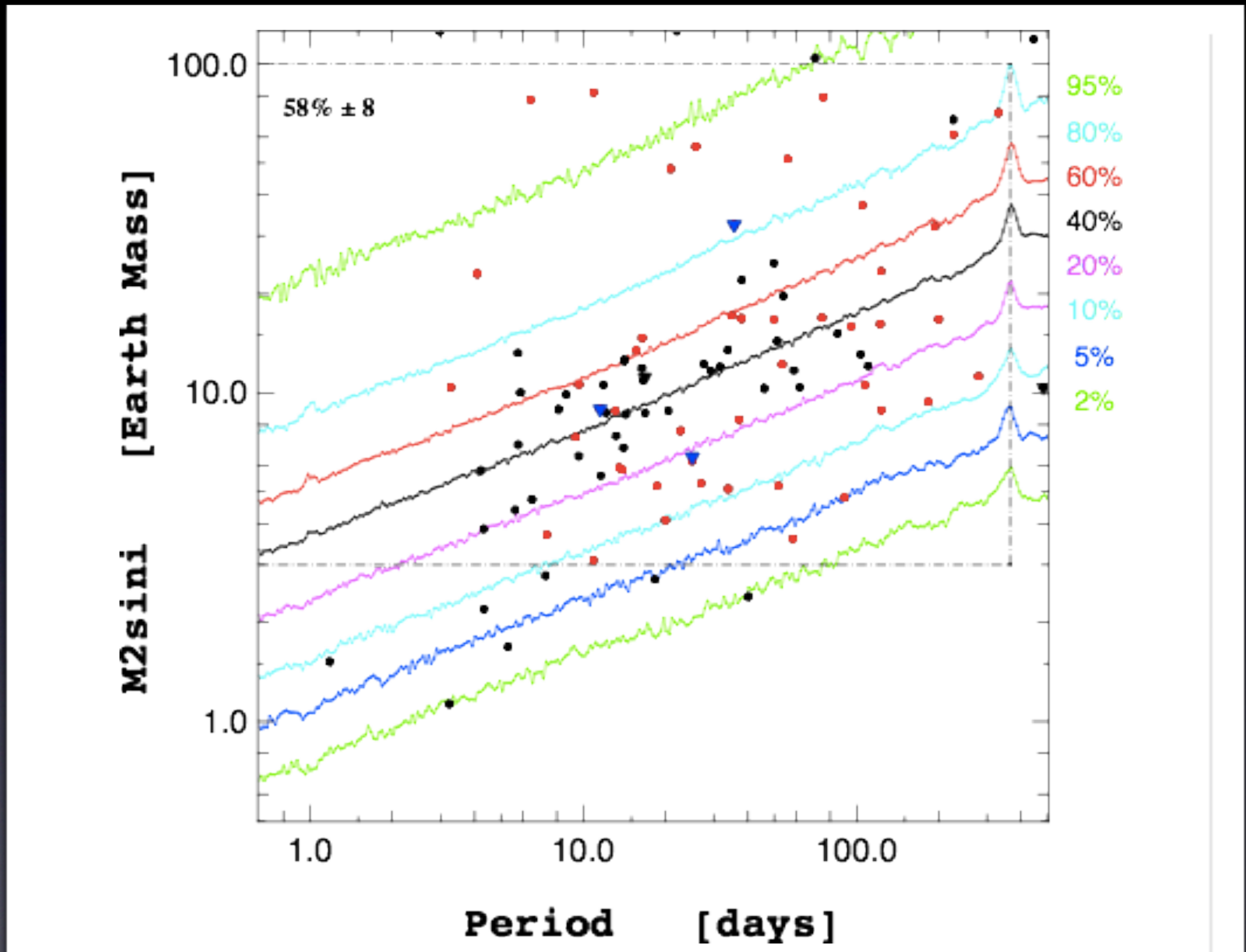
HARPS Super-Earths - Literature Super Earths



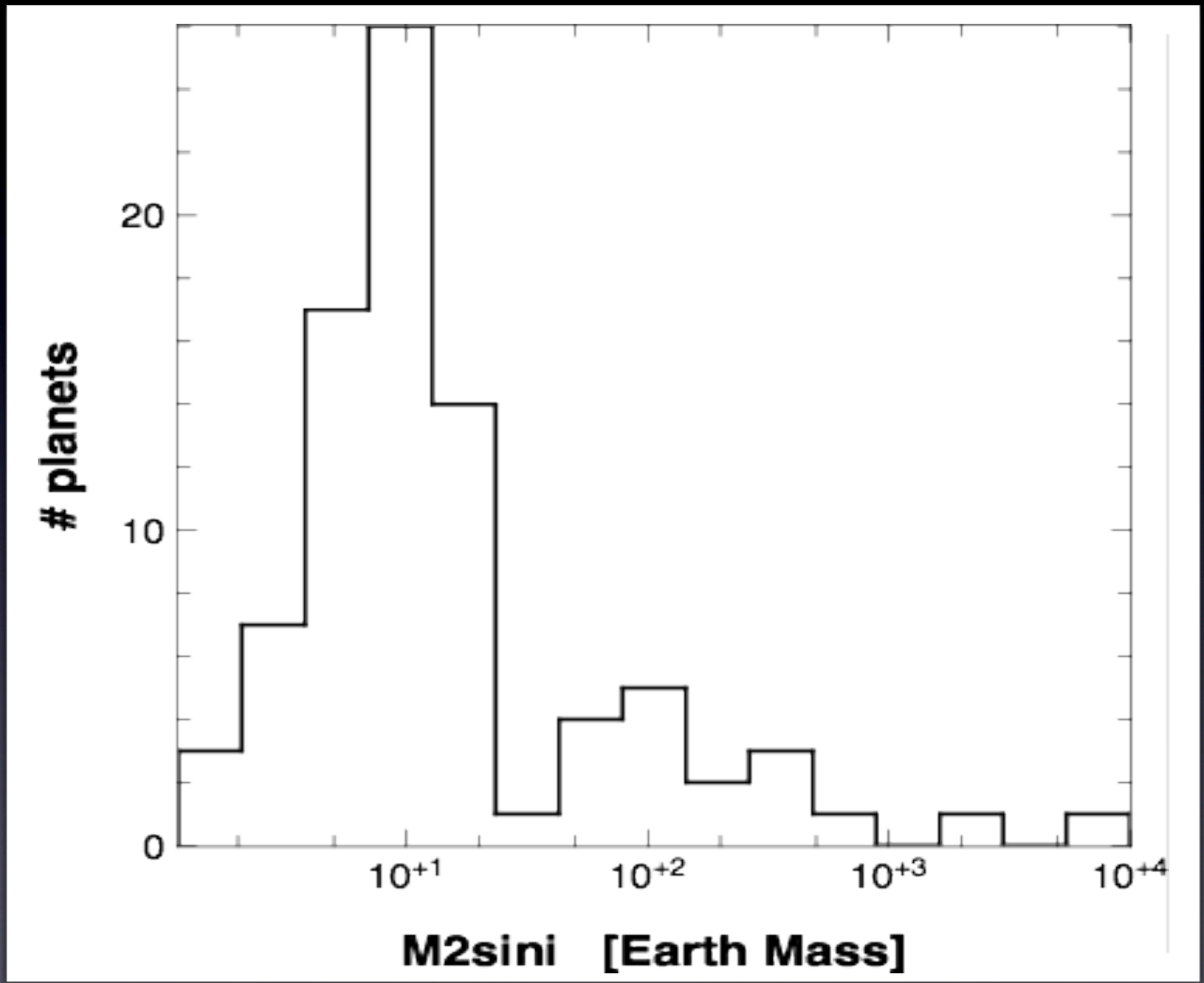
Minimum mass vs log period



Completeness for Super Earths



Detections vs minimum mass, P < 100 days



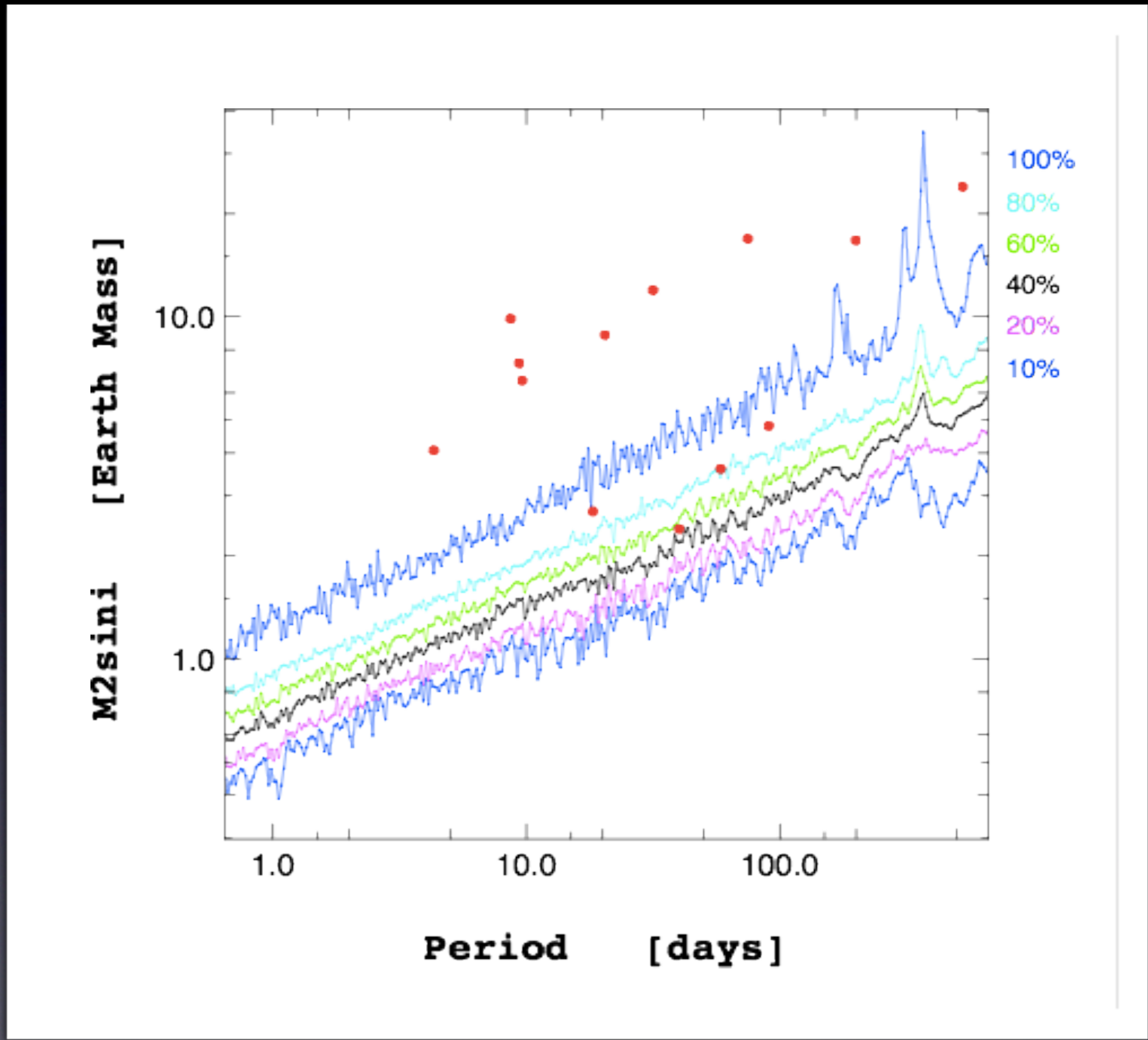
HARPS Rocky Planet Search

Sample of 10 best quiet/bright solar-type stars

Observing strategy for intense monitoring

15 min exposures to average stellar oscillations
3 visits per night to monitor granulation
50 visits per year to monitor rotation
3 to 5 years to monitor activity cycles

Ten stars with Nobs > 165: 15 planets total



α Centauri Bb

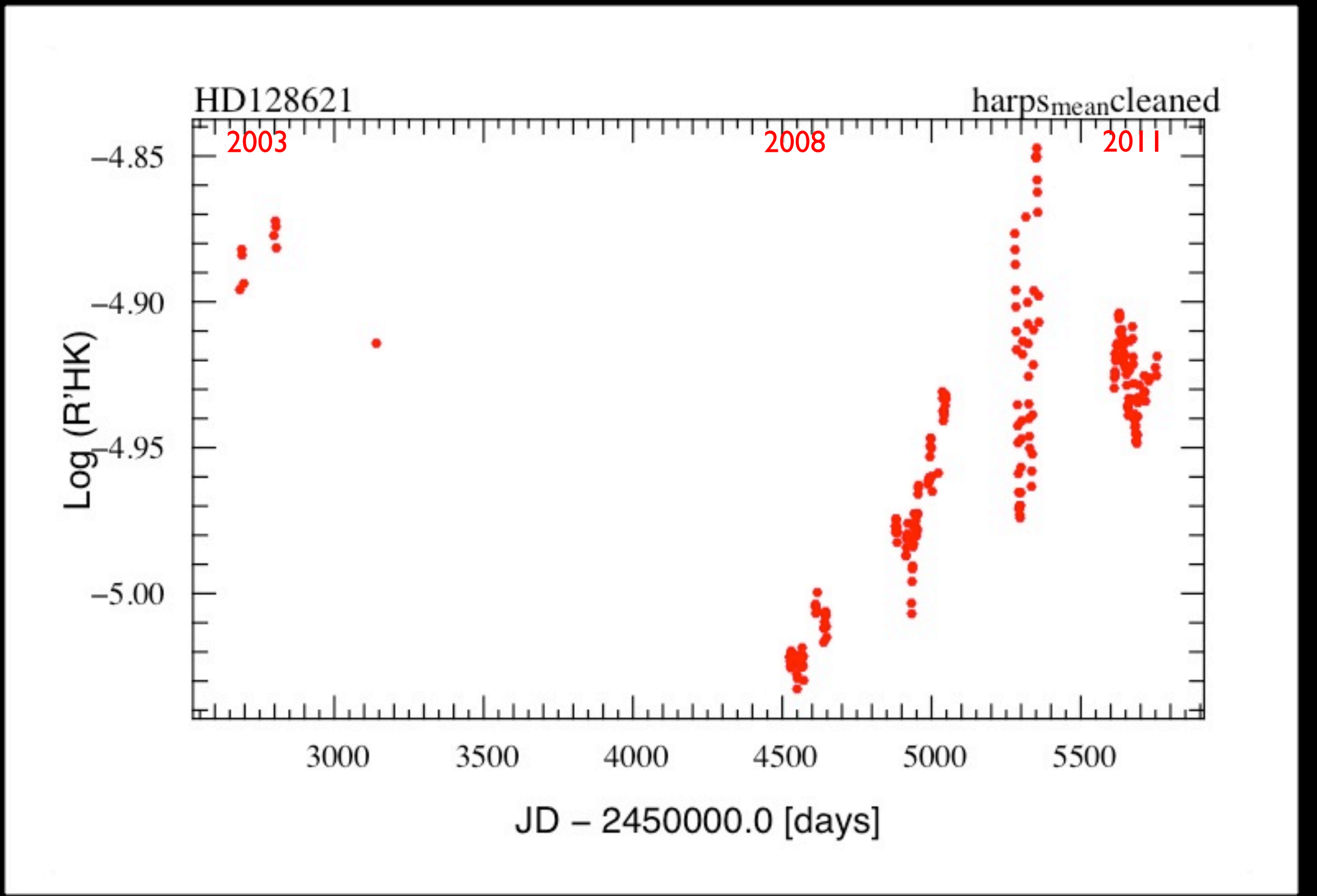
Observing strategy

- P-mode stellar oscillations - 10 min exposures
- Granulation - 3 visits per night
- Reject poor seeing – contamination by α Cen A

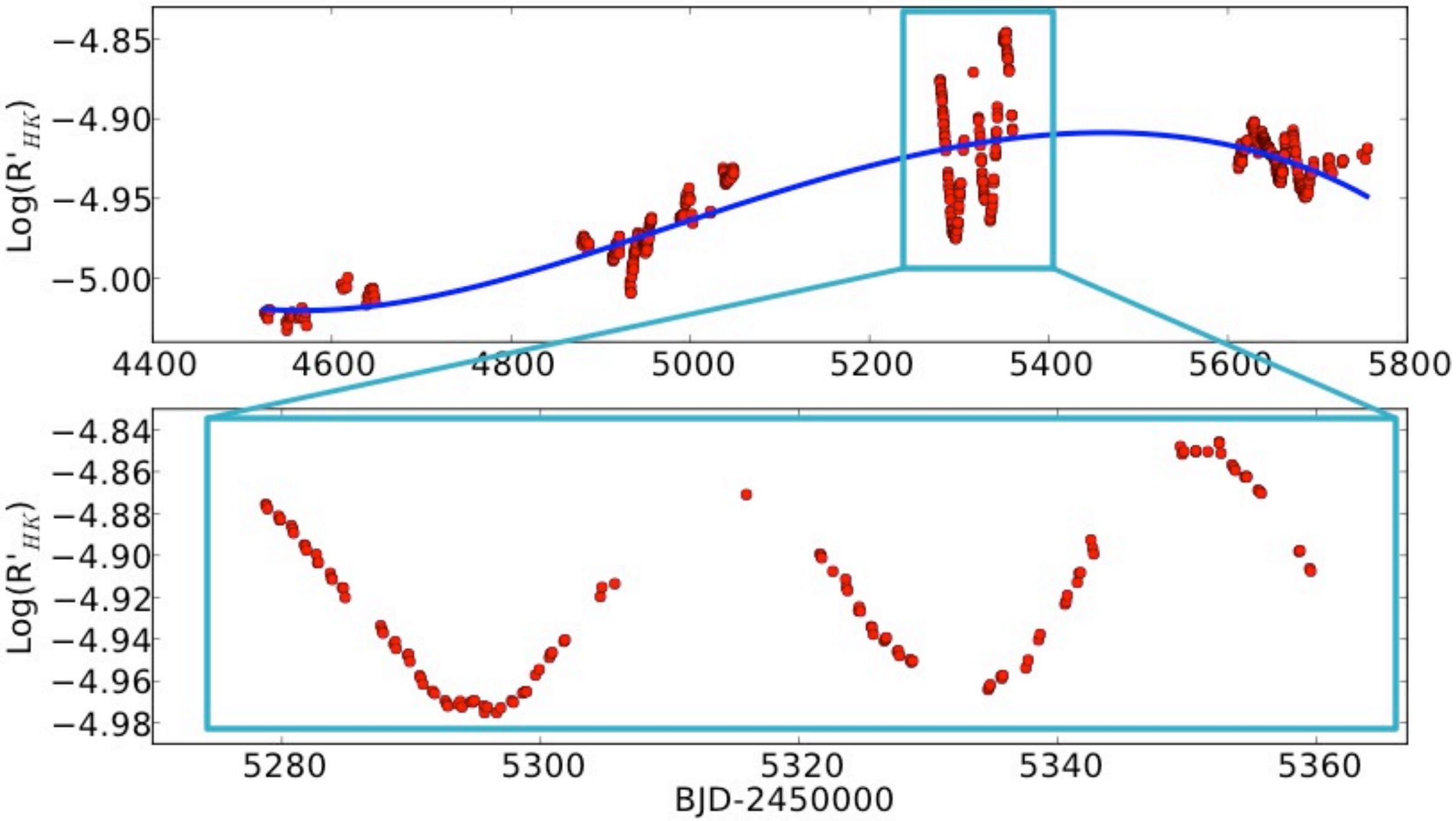
Analysis

- Correct for orbital motion with α Cen A
- Accurate positions for barycentric correction
- Correct for long-term activity cycle using R'_{HK}
- Correct for rotation/spots - remove 3 harmonics
- Adopt an instrumental noise floor of 0.7 m/s

α Centauri B activity cycle

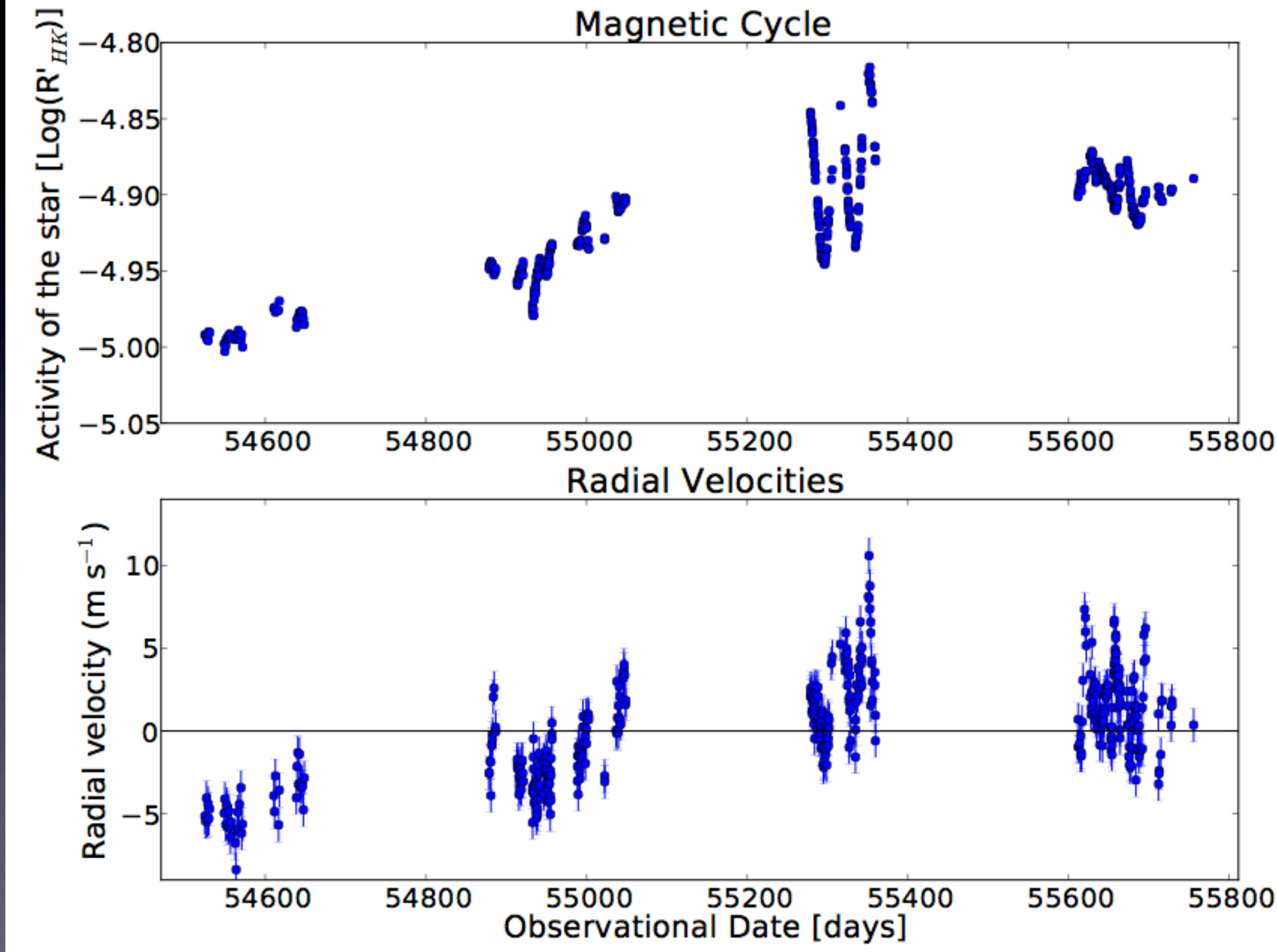


Blow-up of activity cycles near maximum activity



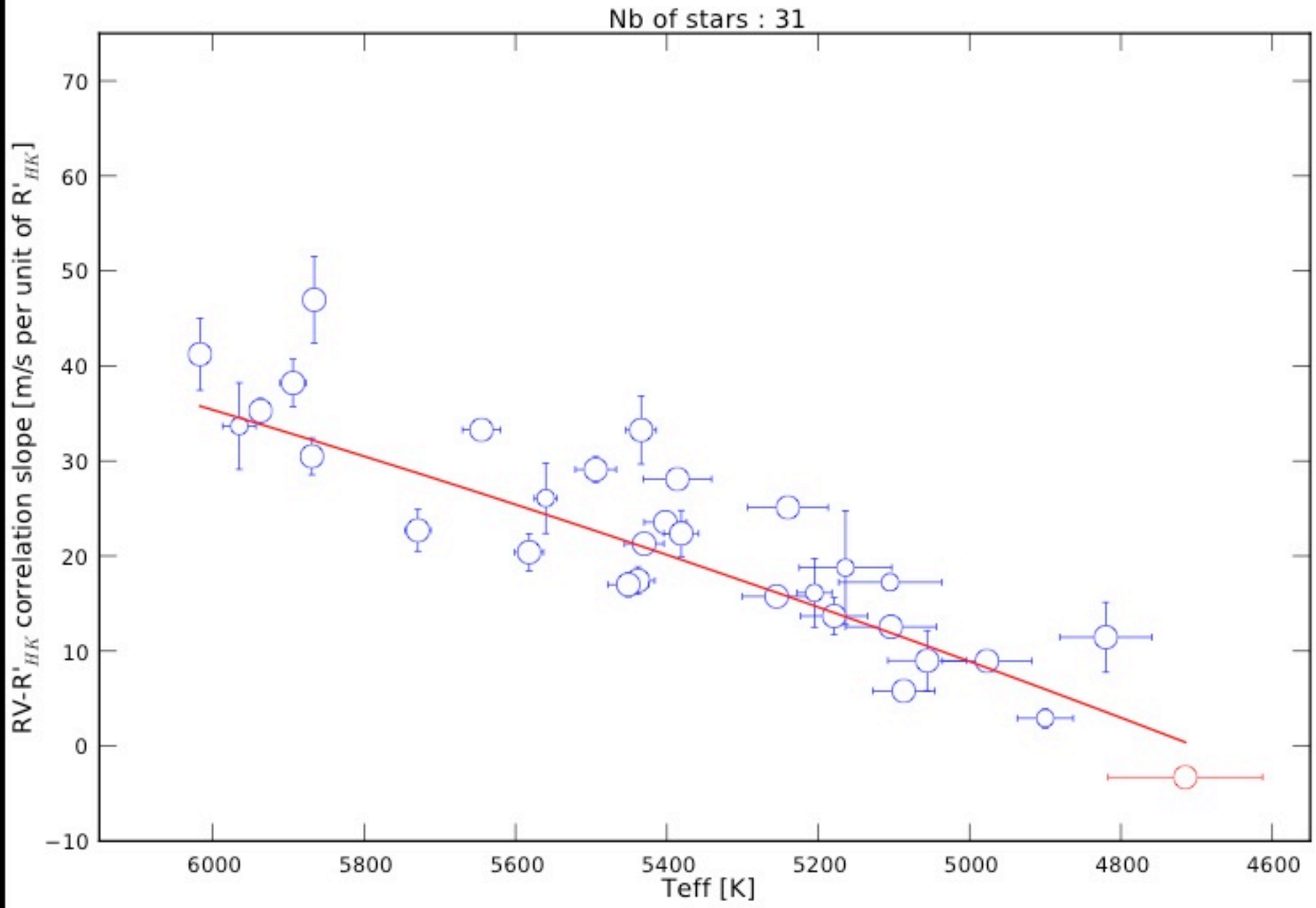
Variation from -5 (solar minimum) to -4.85 (solar max) in 40 days !!!

Log(R'HK) activity and radial velocities

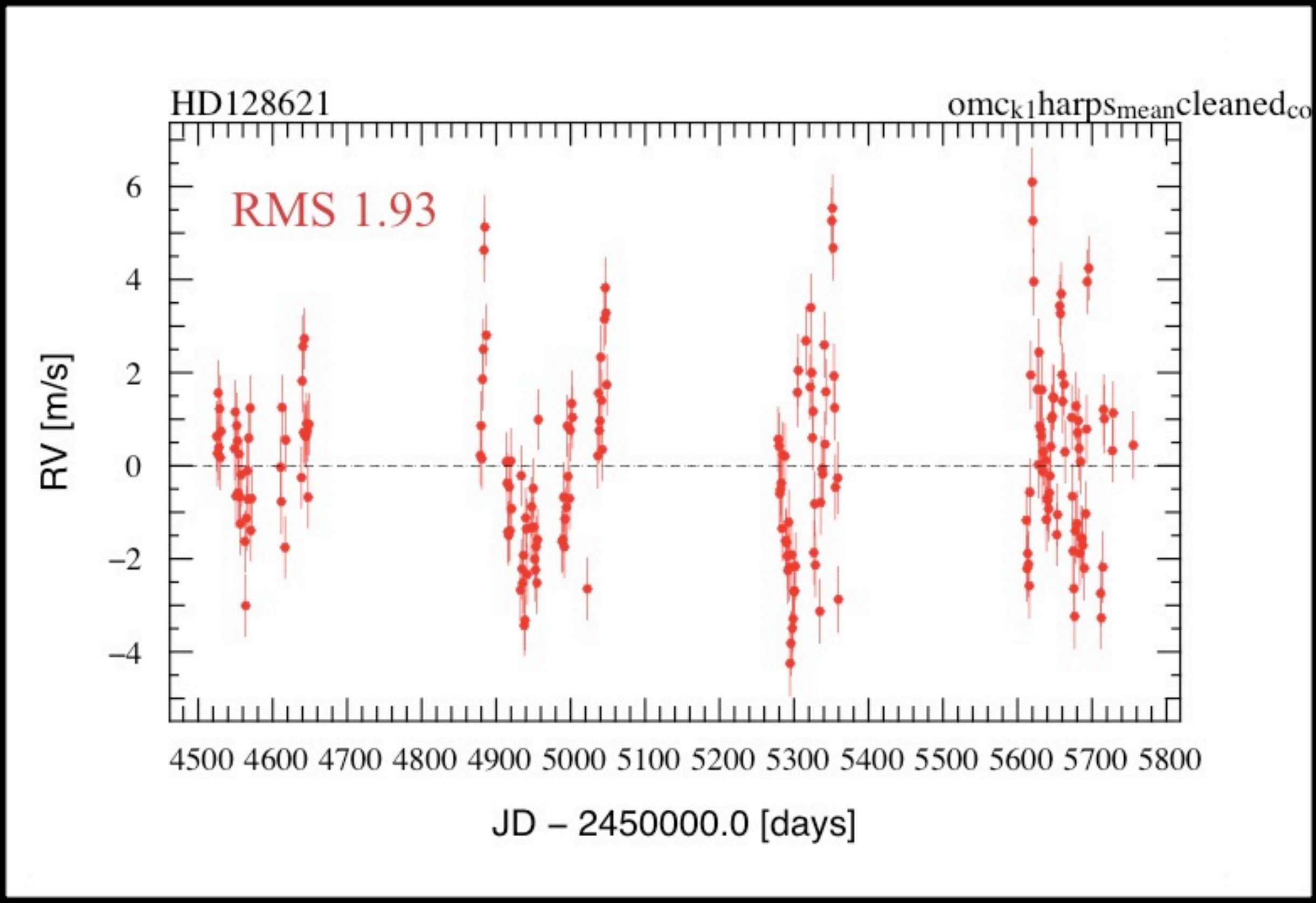


Removing the Magnetic Cycle

$$C_{RV} = (19.04 \pm 0.62) + (3.20 \pm 0.20) \cdot 10^{-2} \cdot \tilde{T}_{eff} + (4.5 \pm 3.1) \cdot 10^{-6} \cdot \tilde{T}_{eff}^2 + (17.8 \pm 3.1) \cdot [Fe/H] + (24.3 \pm 5.2) \cdot [Fe/H]^2 \quad (9)$$

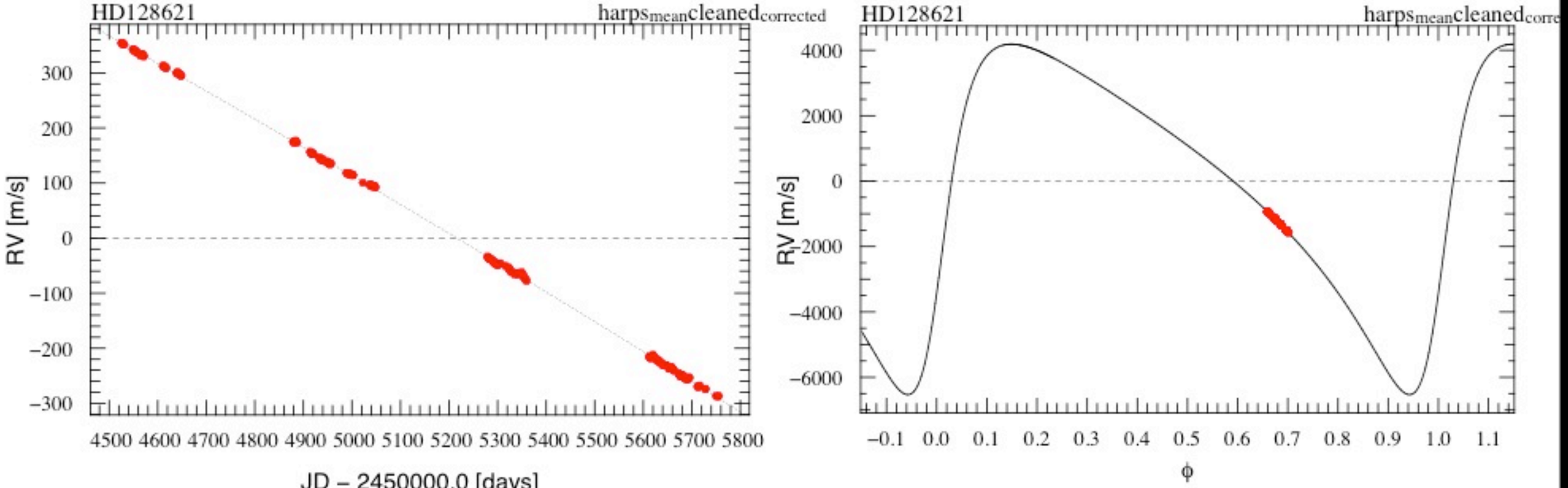


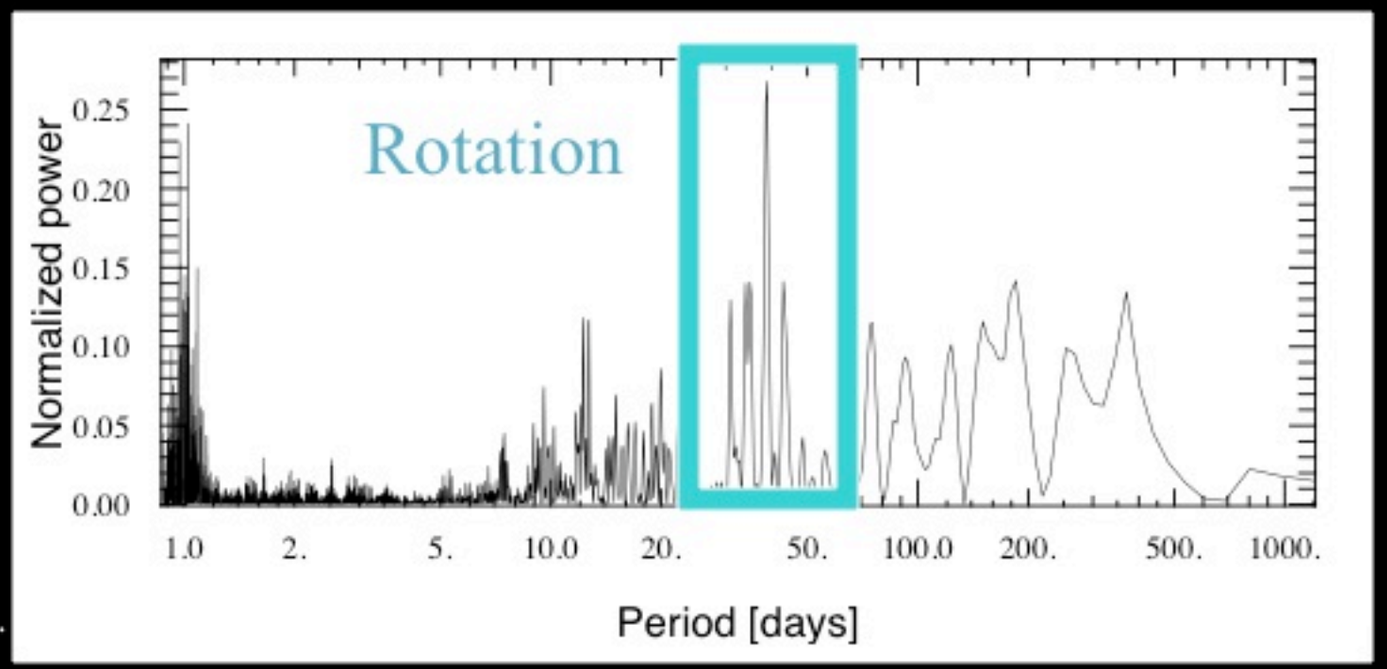
RVs after binary orbit and activity correction



Binary Star

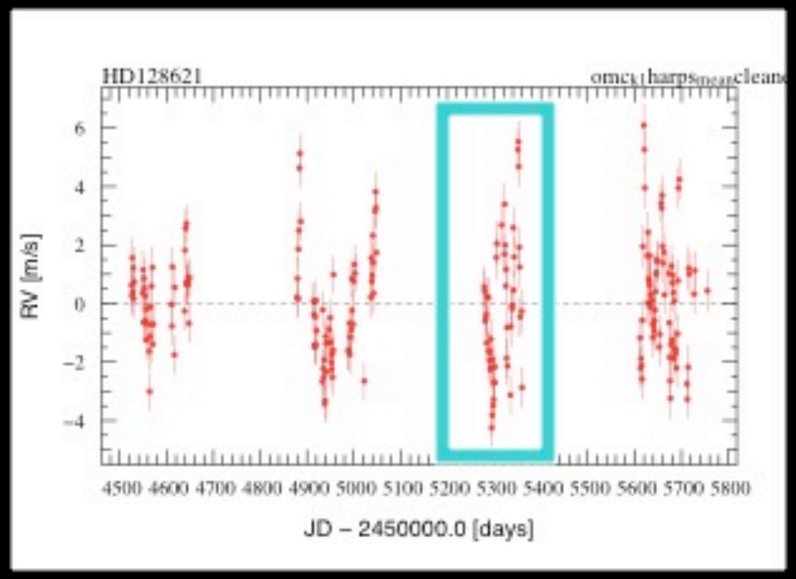
Orbital parameters: Pourbaix et al. 2002

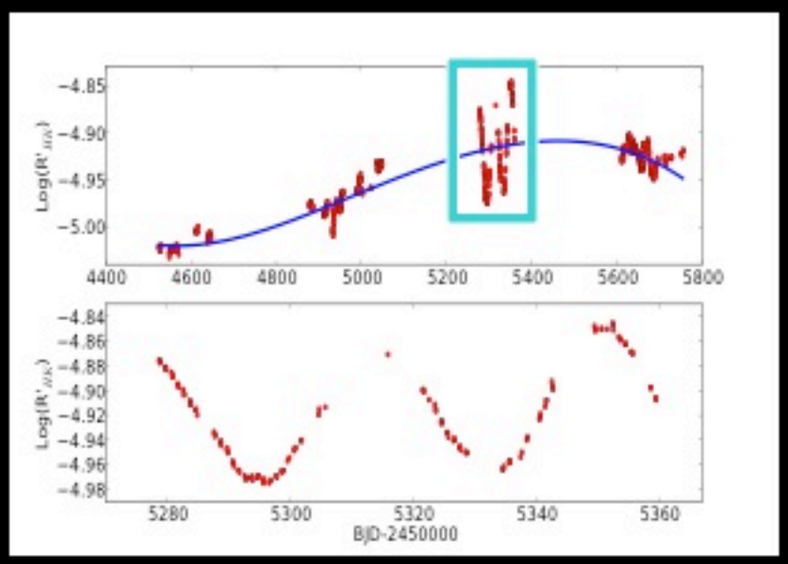


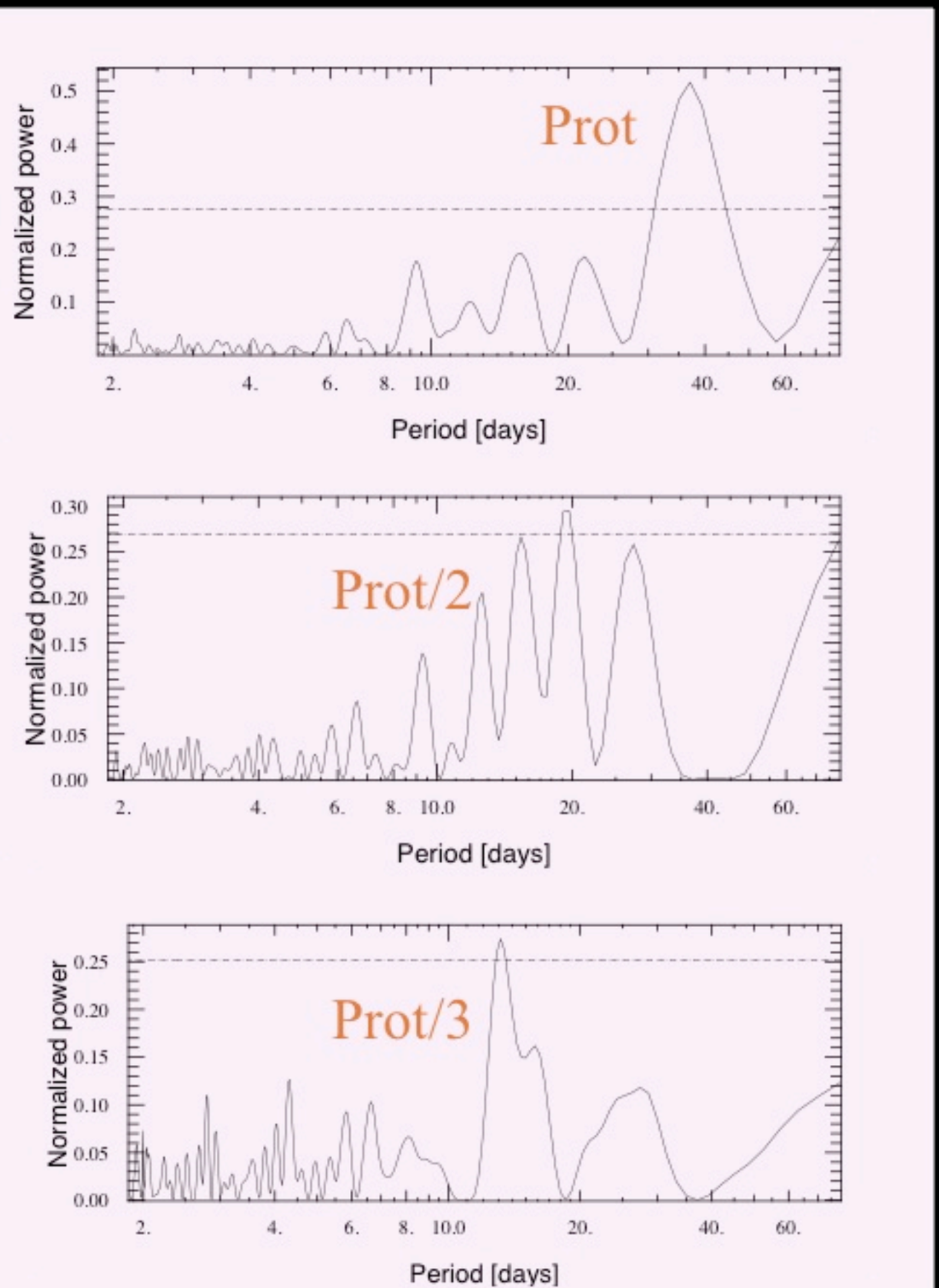


Short-Term Activity

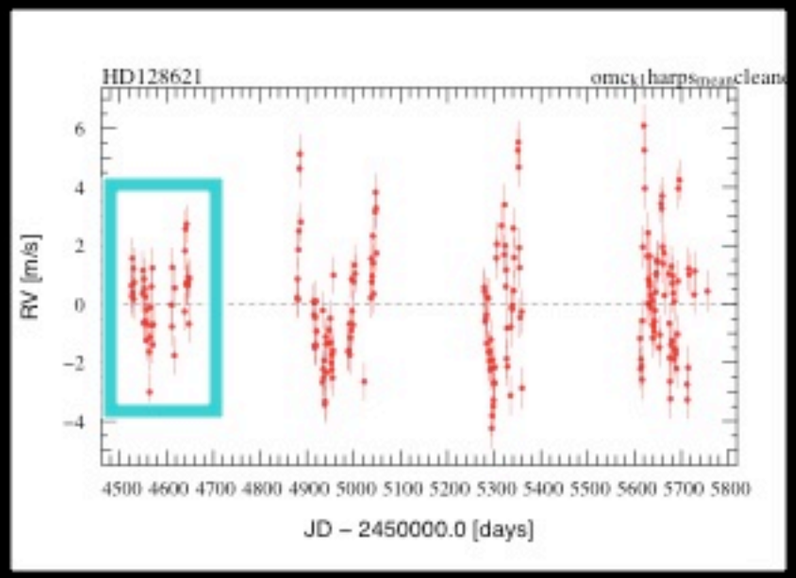
Strong signal at P_{rot} and harmonics because high activity



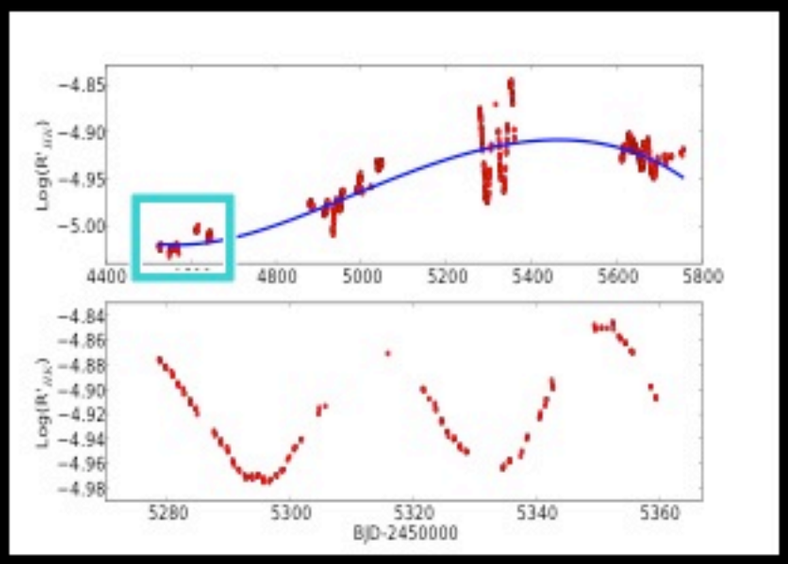


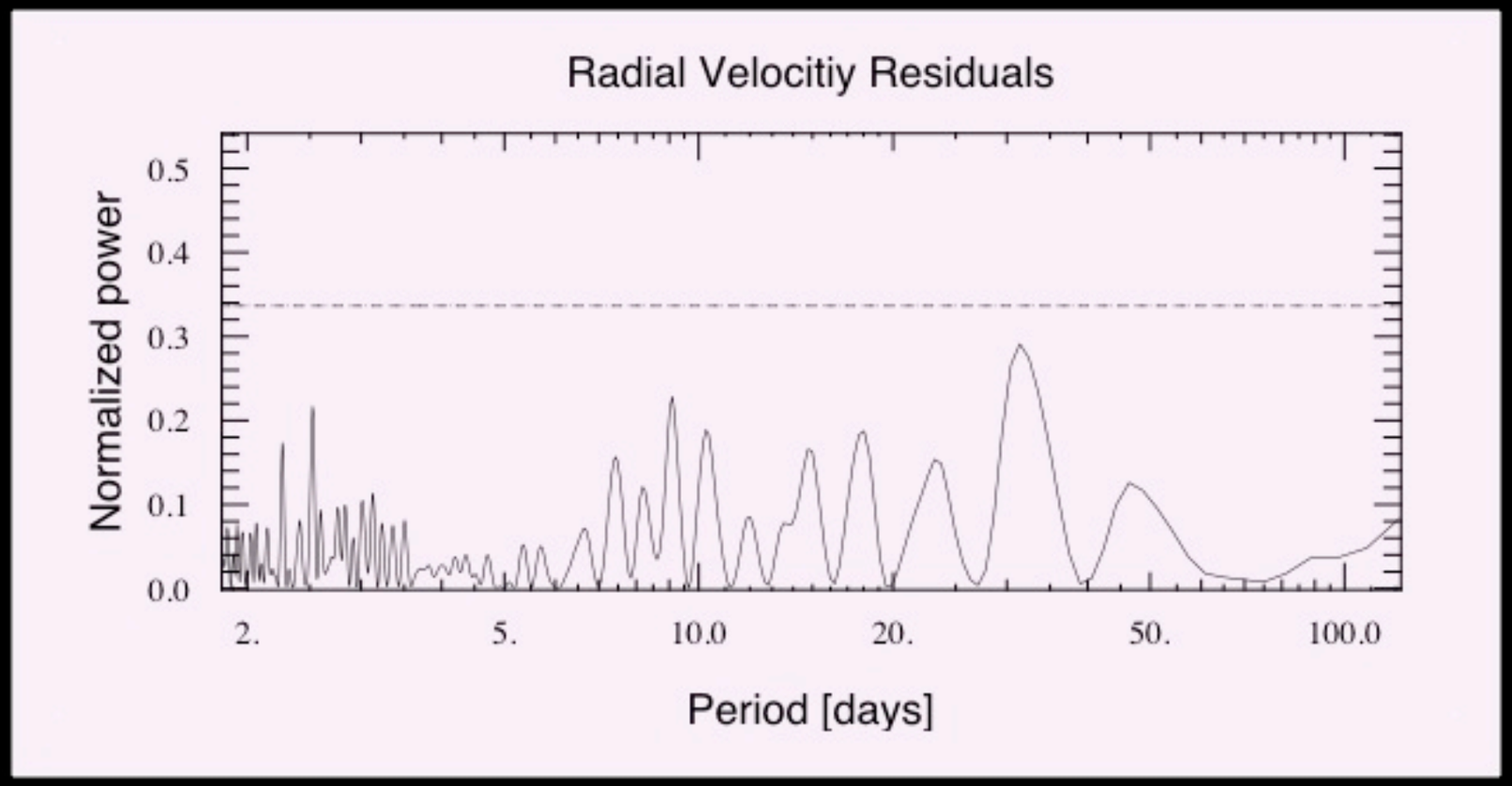


Short-Term Activity

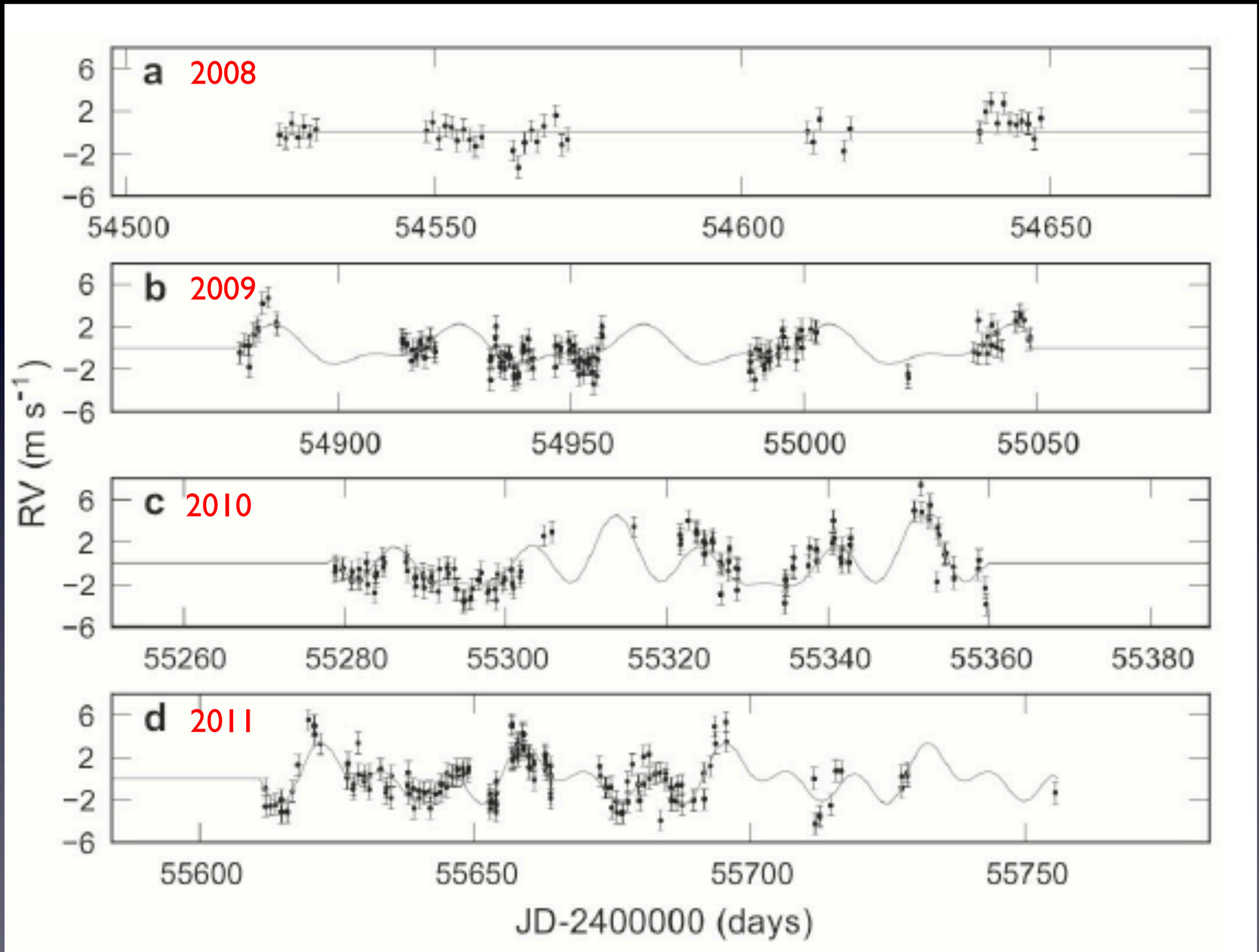


No activity signal because minimum of activity

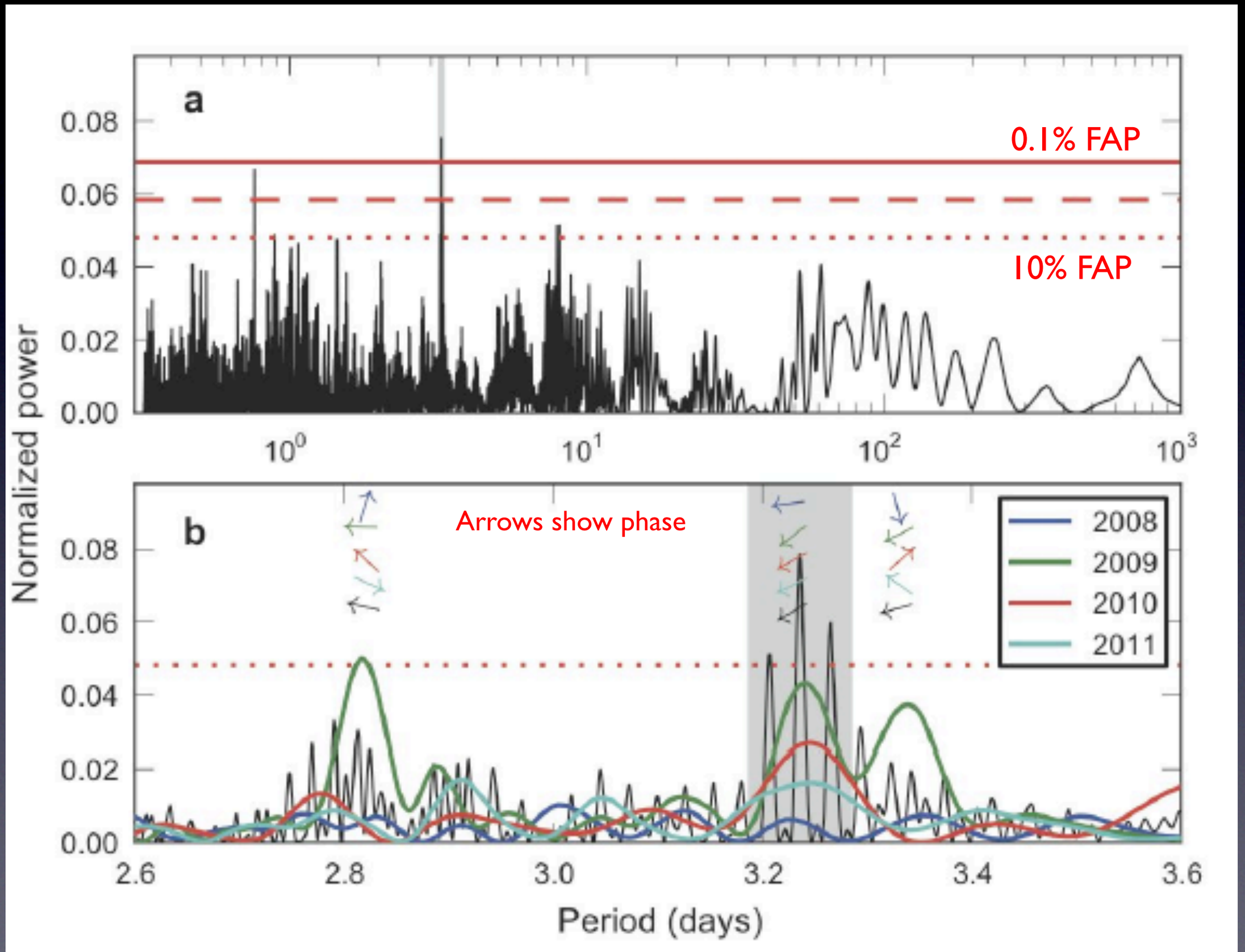




Correction for rotational activity by season

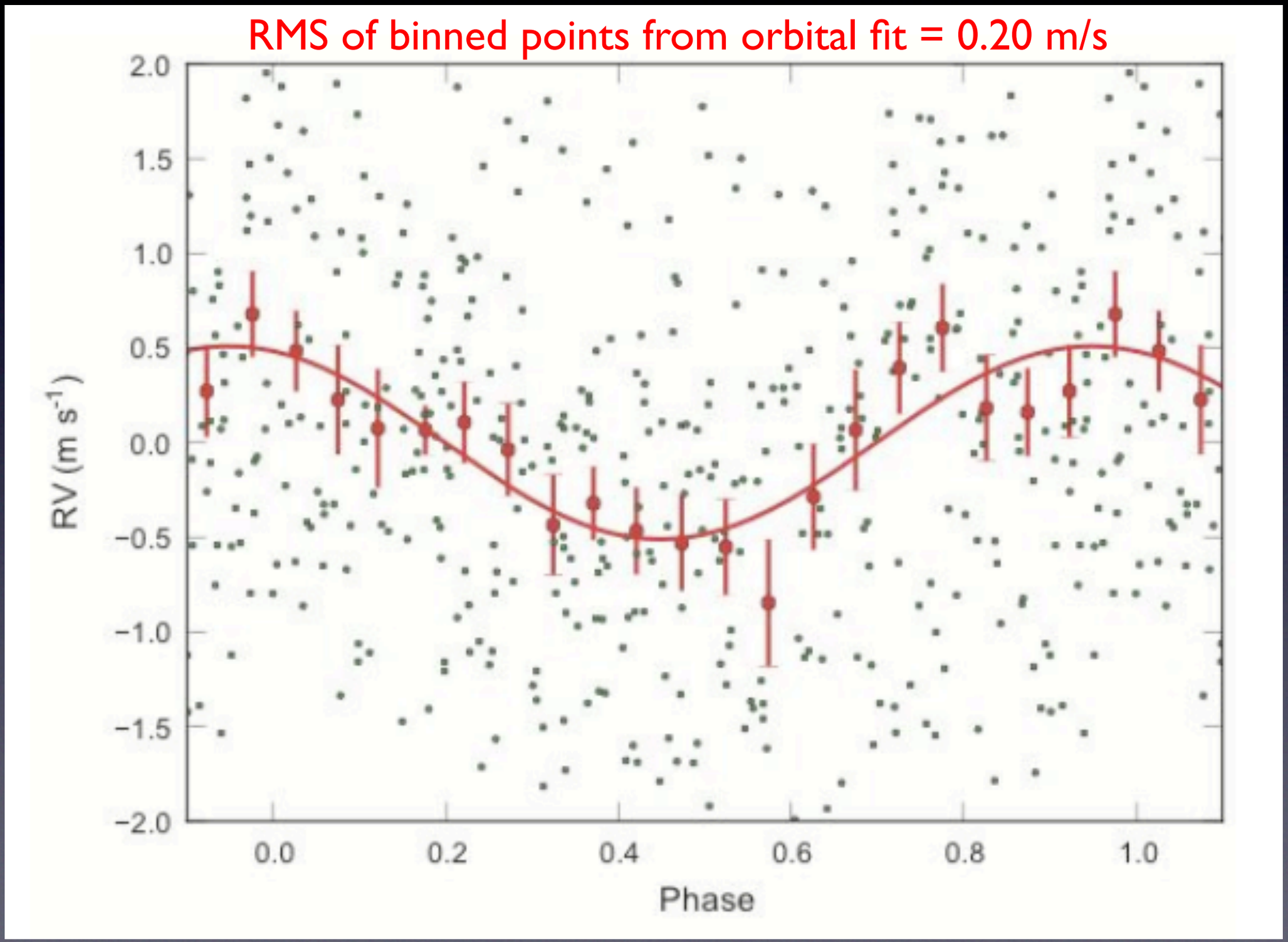


The planetary signal emerges



α Centauri Bb

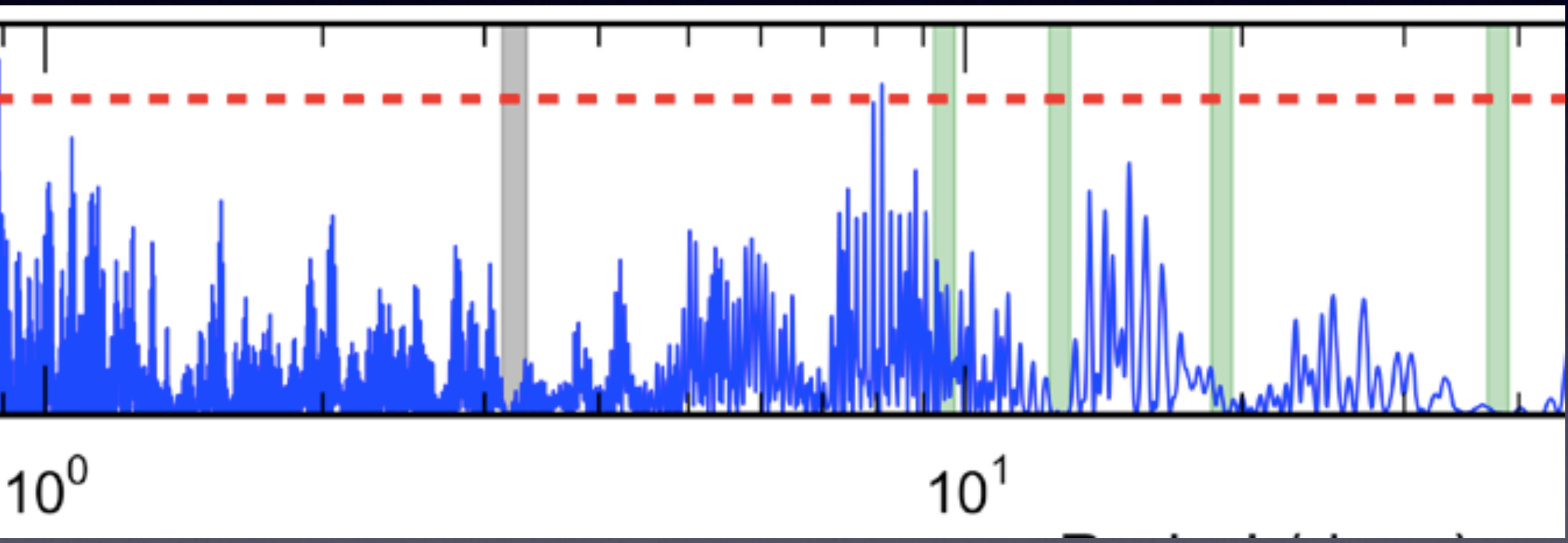
P = 3.23 days, $M_2 \sin i$ = 1.13 M_{Earth}, Nobs = 459



Power spectrum of velocity residuals after a global fit including the planet

3.23 d

Rotation and harmonics



Does the planet transit? HST time to look …

Corrected RVs

RMS 1.93 -> 1.07